Research Articles

Assessing the Efficacy of Dredged Materials from Lake Panasoffkee, Florida: Implication to Environment and Agriculture

Part 2: Pasture Establishment and Forage Productivity

Part 2: Pasture Establishment and Forage Quality <DOI: http://dx.doi.org/10.1065/espr2004.08.212.2>
Part 1: Soil and Environmental Quality Aspect <DOI: http://dx.doi.org/10.1065/espr2004.08.212.1>

Preamble. This series of two papers discusses disposal alternatives of lake-dredged materials and the efficacy and beneficial use of dredged materials from Lake Panasoffkee, Florida in the environment and agriculture. **Part 1** presents the results on the effect of applied lake-dredged materials on soil physico-chemical properties and soil quality at the disposal site. **Part 2** discusses the effect of lake-dredged materials on beef cattle pasture establishment, crude protein and nutrient uptake of bahiagrass in south Florida, U.S.A.

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Abstract

Background, Aims and Scope. Current dredged material disposal alternatives have several limitations. Options for dealing with dredged materials include leaving them alone, capping them with clean sediments, placing them in confined facilities, disposing of them at upland sites, treating them chemically, or using them for wetlands creation or other beneficial uses The ability to reuse lake-dredge materials (LDM) for agricultural purposes is important because it reduces the need for offshore disposal and provides an alternative to disposal of the materials in landfills. Often these materials can be obtained at little or no cost to the farmers or landowners. Thus, forage production offers an alternative to waste management since nutrients in the LDM are recycled into crops that are not directly consumed by humans. The objective of this study (Part 2) were to: (1) assess dredge materials from Lake Panasoffkee, Florida as a soil amendment to establish bahiagrass (BG) in a subtropical beef cattle pasture in Sumter County, Florida; and (2) determine the effect of LDM application on the crude protein (CP) and nutrient uptake of BG. This series of two papers aims at providing assessment of the efficacy of lake-dredged materials especially its implication to environment (soil quality, Part 1) and agriculture (forage quality and pasture establishment, Part 2).

Methods. The experimental treatments that were evaluated consisted of different ratios of natural soil (NS) to LDM: LDM0 (100% NS:0% LDM); LDM25 (75% NS:25% LDM); LDM50 (50% NS:50% LDM); LDM75 (25% NS:75% LDM); and LDM100 (0% NS:100% LDM). Bahiagrass plots at its early establishment were cut to a 5-cm stubble height on Julian days 112 and harvested to the same stubble height on Julian days 238 and on Julian days 546 following the double-ring method. Field layout was based on the principle of a completely randomized block design with four replications. Plant samples harvested at 546 Julian days were ground to pass through a 1-mm mesh screen in a Wiley mill. Ground forage was analyzed for crude protein. Ground forage samples were also analyzed for tissue P, K, Ca, Mg, Mn, Cu, Fe, Al, and Mo concentrations using an ICP spectroscopy. The effects of dredged materials addition on forage yield and on crude protein and nutrient uptake that were taken at 546 Julian days were analyzed statistically following the PROC ANOVA procedures.

Results and Discussion. Part 1 of this study demonstrated that the heavy and trace metal contents of LDM were below the probable effect levels and threshold effect levels. As such, the agricultural or livestock industry could utilize these LDM to produce forages. Results showed consistently and significantly ($p \leq 0.001$) higher BG biomass production and CP from plots amended with LDM than those of BG planted on plots with 0% LDM. Forage yield of BG during its establishment increased linearly (Forage Yield = 1724.3 + 25.64*LDM; $R^2 = 0.83$; $p \leq 0.0001$) with increasing rates of LDM application. The CP of BG also varied significantly with varying levels of LDM applications. The tissues of BG with 100% LDM had the greatest CP content while the lowest CP content was from the control plots (LDM0). The CP of BG increased linearly with increasing rates of LDM application. The crude protein response to BG application can be described by a linear equation: **Crude Protein = 10.38 + 0.052*LDM; $R^2 = 0.85$ $p \leq 0.0001$.** Addition of LDM had increased the levels of Ca by about 1811% when compared with the level of soil Ca among plots with no LDM application. Liming the field could have some direct and indirect effects on the chemical status of the soils. The physiological functions performed by Ca in plants are not clearly defined, but it has been suggested that Ca favors the formation of and increases the protein content of mitochondria.

Conclusions. Beneficial uses of dredged materials from LP, Florida are both economical and environmental. Often these materials can be obtained at little or no cost to the farmers or landowners. Results showed that dredged materials can be used as soil amendments (lime and fertilizer) for early establishment of BG in beef cattle pastures. Environmentally, dredging of sediments that are rich in $CaCO_3$ should restore the 19.4-sq km LP by removing natural sediments from the lake bottom to improve the fishery, water quality, and navigation of the lake. The nutritional uptake of BG grown in unfertile sandy soils of Sumter County was enhanced significantly ($p \leq 0.001$) by LDM addition. Uptake of TKN, TP, K, Ca, and Mg were remarkably increased as a result of LDM.

Recommendation and Outlook. Land application of LDM from LP may not only provide substantial benefits that will enhance the environment, community, and society in south Florida, but also in other parts of the world especially those areas with forage-based beef cattle pastures and similar climatic conditions. The heavy and trace metal contents of these materials were below the PEL and TEL (see Part 1). As such, the agricultural or livestock industry could utilize these LDM to produce forages. LDM should be regarded as a beneficial resource, as a part of the ecological system. Although our results have demonstrated the favorable and beneficial effects of added LDM on the early establishment of BG in pasture fields., further studies are still needed not only in pastures of south Florida, but also in other areas with subtropical or tropical climatic conditions to determine whether the environmental and ecological implications of LDM application are satisfied over the longer term.

Keywords: Agriculture; bahiagrass; beef cattle; dredged materials; forage-based pasture

1 Background, Aim and Scope

In the preceding paper (Part 1, see Sigua et al. 2004), the unique physical and chemical properties of lake-dredged materials from LP, Florida and its effects on the environment and soil quality of beef cattle pastures in subtropical U.S.A have been described. Environmental impact assessment is an important pre-requisite to many dredging initiatives (Sigua et al. 2003, Patel et al. 2001, Sigua et al. 2000). Disposal and environmental quality of dredged sediments from navigational channels have been judged as beneficial by combinations of physical, chemical, and biological analyses for over 30 years. However, many people in the scientific community find this approach objectionable since the data does not provide sufficient environmental protection information because several site-specific geochemical and biological factors are typically excluded from the decision-making process (Wenning and Woltering 2001).

Options were explored in the beneficial usage of lake-dredged sediments. One option was to use the sediment as a soil enhancement for agricultural use. Forage production offers an alternative to waste management since nutrients in the waste are recycled into crops such as BG that are not directly consumed by humans. Bahiagrass is a good general-use pasture grass that can tolerate a wide range of soil conditions and close grazing, and withstands low fertilizer input (Burson and Watson 1995, Kidder 1999). It has the ability to produce moderate yields on soils of very low fertility and easier to manage than other improved pasture grasses (Chambliss 1999). The bottom sediment materials from lakes, river, and navigational channels usually are composed of upland soil enriched with nutrients and organic matter. While preliminary efforts are underway to provide information to establish criteria for land disposal, testing procedures for possible land disposal of contaminated sediments are still in their developing stages, we hypothesized that these materials should be regarded as a beneficial resource to be used productively and not to be discarded as spoil materials.

The sediment removal project in Lake Panasoffkee (LP) is being assessed to determine whether the operation satisfies environmental objectives or expectations. Additional research on disposal options of dredged materials are much needed to supply information on criteria testing and evaluation of the physical and chemical impacts of dredged materials at the disposal site. There is still much to be learned from this project. The goal of this study was to explore the beneficial and ecological use of dredge materials from LP, Florida in improving the physico-chemical properties of existing sandy soils (Part 1) and for sustaining forage productivity in subtropical beef cattle pastures (Part 2) with calcium carbonate- and organic-enriched dredged materials. The LDM, if found to be beneficial, could be removed from the spoil containment areas, trucked to other locations and incorporated into existing pasture fields. The objectives of this study were to: (1) assess LDM as a soil amendment to establish BG in a subtropical beef cattle pasture in Sumter County, Florida; and (2) determine the effect of LDM application on the crude protein and nutrient uptake of BG in south Florida, U.S.A.

2 Methods

2.1 Study site

The study site is located in Sumter County (Coleman Landing; 28.798°N; 82.103°W), Florida (**Fig. 1**). Most of the soils at Sumter County formed in sandy marine or eolian deposits and have a water table depth of 102 to 203 cm for more than 6 months during most years. These soils are hyperthermic, uncoated typic quartzipsamments (USDA 1988). The climate of Sumter County is characterized by long, warm, and relatively humid summers and mild dry winters. The average total annual precipitation (1988–2001) in the area was about 1,191 mm with approximately half (56%) this amount occurring during the mid-June through mid-August period (see Fig. 2, Part 1). The lowest average temperature of 15°C occurs during January. The highest average temperature in the mid- to upper-25°C range occurs regularly from June through September (see Fig. 2, Part 1).

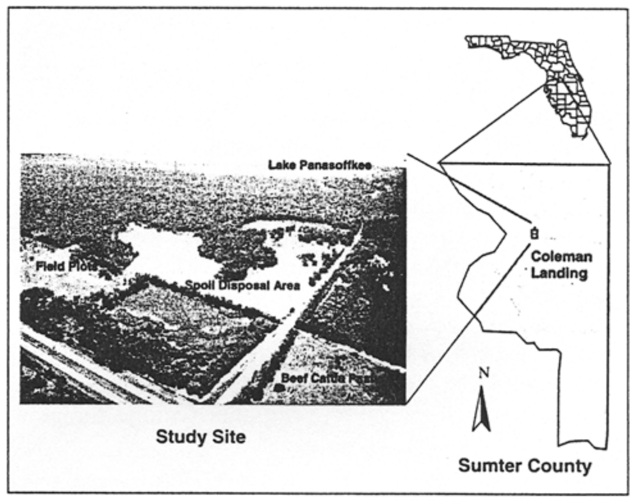

Fig. 1: Location of the study site and aerial view of the dredging site at Lake Panasoffkee, Sumter County, FL

2.2 Field site preparation and experimental design

This field study was adjacent to the Coleman Landing spoil disposal site in Sumter County, FL (see Fig. 1). Each plot (961 m^2) was excavated to a depth of about 28 cm, and existing NS and organic materials were completely removed. Excavated NS materials were placed at the south end of the test plots. Existing vegetation from each plot was totally removed prior to backfilling each plot with different ratios of NS and LDM: (100% NS + 0% LDM); (75% NS + 25% LDM); (50% NS + 50% LDM); (25% NS + 75% LDM); and (0% NS + 100% LDM). These ratios of NS to LDM represent the treatment combinations of LDM0; LDM25; LDM50; LDM75; and LDM100, respectively. Natural soils that were excavated were backfilled to each plot along with LDM that were hauled from the adjacent settling pond (see Fig. 1) on December 15, 2001. The total amount of LDM and NS that was placed back on each test plot was in accordance with the different ratios of LDM and NS that were described above. After mixing the NS and LDM, each of the test plots was disked to a uniform depth of 28 cm. Plots were disked in an alternate direction until LDM and NS were uniformly mixed. Each plot was seeded with BG at a rate of 6 kg $plot^{-1}$, followed by dragging a section of chain link fence across each test plot to ensure that BG seeds were in good contact with the NS and LDM. Field layout was based on the principle of a completely randomized block design with four replications.

2.3 Chemical analysis of LDM

Prior to LDM applications in the field, a private laboratory (Flowers Chemical Laboratories, Inc.) in Leesburg, FL performed the physical and chemical analyses of LDM that were used in the study. Results and methods of analyses are given in Table 1. Chemical analyses of LDM are important for its safe and effective use on soils used to grow forages.

2.4 Plant sampling and nutritive value analysis

Bahiagrass plots at its early establishment were cut to a 5-cm stubble height on Julian days 112 and harvested to the same stubble height on Julian days 238 and on Julian days 546 following the double-ring method of Williams and Hammond (1999). Yield measurements of BG from 20 plots were taken from the same location (1.5 x 1.5 m) during the three harvest dates. The harvest area (2.25 m^2) on each plot was permanently marked, using yellow flags placed at the four corners of a 1.5 x 1.5 m quadrant. Freshly cut aboveground growth was oven-dried at 60°C for 24 hours at the USDA-ARS Laboratory, Brooksville, FL. Plant samples harvested at 546 Julian days were ground to pass through a 1-mm mesh screen in a Wiley mill. Ground forage was analyzed for CP (Gallagher et al. 1976). Ground forage samples were also analyzed for tissue P, K, Ca, Mg, Mn, Cu, Fe, Al, and Mo concentrations using an ICP spectroscopy at the University of Florida Analytical Research Laboratory, Gainesville, FL. Forage was predigested in a mixture of nitric and perchloric acids using standard methods of the University of Florida Analytical Research Laboratory (Hanlon and Devore 1989). Nutrient uptake of BG in Julian days 546 was calculated using the equation given below.

$$NU_{TP,\,K,\,Ca,\,Mg,\,Mn,\,Cu,\,Fe,\,Al,\text{ and }Mo} = CN_{TP,\,K,\,Ca,\,Mg,\,Mn,\,Cu,\,Fe,\,Al,\text{ and }Mo} \times DMY \quad (1)$$

where

NU = nutrient uptake (kg ha^{-1})

CN = concentration of nutrients (g kg^{-1})

DMY = calculated forage yield (kg ha^{-1})

2.5 Statistical analysis

The forage yield characteristic of BG in beef cattle pasture taken at 112, 238, and 546 Julian days after seeding was analyzed statistically following the analysis of variance using the SAS PROC GLM model (SAS 2000). Where the F-test indicated a significant ($p \le 0.05$) effect, means were separated, following the method of least significance difference test (LSD), using appropriate error mean squares (SAS 2000). The effects of dredged materials addition on CP and nutrient uptake taken on 546 Julian days were analyzed statistically following the PROC ANOVA procedures (SAS 2000). Where the F-test indicated a significant ($p \le 0.05$) effect, means were separated, following the method of LSD test, using appropriate mean squares (SAS 2000).

Table 1: Selected chemical properties of the dredged materials from Lake Panasoffkee

Parameter	Unit	Dredged Materials	Analytical Method
pH	pH unit	7.8 ± 0.2	EPA150.1
Organic Carbon (OC)	g kg^{-1}	127.0 ± 1.5	EPA9060
Potassium (K)	mg kg^{-1}	4.3 ± 1.8	EPA6020
Total Phosphorus (TP)	mg kg^{-1}	1.6 ± 1.2	EPA6010
Total Nitrogen (TKN)	mg kg^{-1}	6.9 ± 0.3	EPA351.2
Nitrate-N	mg kg^{-1}	0.2 ± 0.05	EPA351.1
Nitrite-N	mg kg^{-1}	0.3 ± 0.05	EPA351.1
Ca (as $CaCO_3$)	g kg^{-1}	828 ± 2.1	ASTM C25-95
Mg (as $MgCO_3$)	g kg^{-1}	9 ± 3.0	ASTM C25-95
Lead (Pb)	mg kg^{-1}	5.2 ± 1.3	EPA6020
Zinc (Zn)	mg kg^{-1}	7.0 ± 0.6	EPA6020
Arsenic (As)	mg kg^{-1}	4.4 ± 0.1	EPA6020
Copper (Cu)	mg kg^{-1}	8.7 ± 1.2	EPA6020
Iron (Fe)	mg kg^{-1}	710.0 ± 1.3	EPA6020
Mercury (Hg)	mg kg^{-1}	0.01 ± 0.02	EPA7471
Selenium (Se)	mg kg^{-1}	0.02 ± 0.02	EPA6020
Cadmium (Cd)	mg kg^{-1}	2.5 ± 0.1	EPA6020
Nickel (Ni)	mg kg^{-1}	14.6 ± 6.4	EPA6020

3 Results

3.1 Forage yield

The forage yield of BG at 112, 238, and 546 Julian days after seeding are shown in **Fig. 2**. Forage yield of BG varied significantly ($p \leq 0.001$) among plots with LDM additions. The greatest forage yield of 673 ± 233 kg ha^{-1} at Julian day 112 was from plots amended with 50% LDM while BG in plots amended with 100% LDM and 75% LDM had the highest forage yield at Julian days 238 and 546 with average forage yield of 3,349 ± 174 and 4,109 ± 220 kg ha^{-1}, respectively (see Fig. 2). The lowest forage yield of 89 ± 63, 1,513 ± 166, and 1,263 ± 116 kg ha^{-1} were from the control plots for Julian days 112, 238, and 546, respectively (see Fig. 2). The average forage yield increase of BG in plots amended with LDM (averaged across treatments) was 512%, 82%, and 173% when compared with BG in control plots with 0% LDM for Julian days 112, 238, and 546, respectively (see Fig. 2). These data show the favorable influence that LDM had on forage yield of BG during its early establishment in subtropical beef cattle pastures.

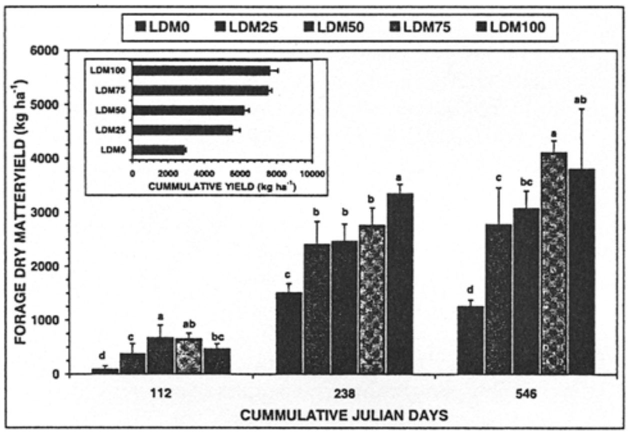

Fig. 2: Forage yield of bahiagrass (Julian days 112–546) as affected by varying levels of dredged materials application. Forage yield from plots with or without LDM are significantly different ($p \leq 0.05$) at Julian days 112, 238, and 546 when superscripts located at top of bars are different

Mean forage yield of BG during Julian day 112 in plots with 50% LDM of 673 ± 233 kg ha^{-1} was not significantly different from that in plots with 75% LDM (654 ± 106 kg ha^{-1}), but was greater than that in plots with 25% LDM (378 ± 185 kg ha^{-1}) and 0% LDM (see Fig. 2). For Julian day 238, the greatest forage yield among plots amended with LDM was from plots with 100% LDM (3,349 ± 174 kg ha^{-1}). The lowest forage yield of 1,513 ± 166 kg ha^{-1} was from plots with 0% LDM. Mean forage yield of BG in plots with 50% LDM of 2,467 ± 320 kg ha^{-1} was not significantly different from that in plots with 75% LDM (2,467 ± 320 kg ha^{-1}) and 25% LDM (2,409 ± 423 kg ha^{-1}), but was greater than that in plots with 0% LDM (see Fig. 2).

For Julian day 546 (78 weeks), mean forage yield of BG in plots with 100% LDM of 3,804 ± 1120 kg ha^{-1} was comparable with that of BG yield in plots with 75% LDM (4,109 ± 220 kg ha^{-1}) and 50% LDM (3,077 ± 322 kg ha^{-1}). However, mean forage yield of BG in plots with 75% LDM was significantly higher than the mean forage yield of BG in plots with 50%, 25% (2,780 ± 678kg ha^{-1}), and 0% (1,263 ± 116 kg ha^{-1}) LDM (**Fig. 3**). The linear yield response of BG to different

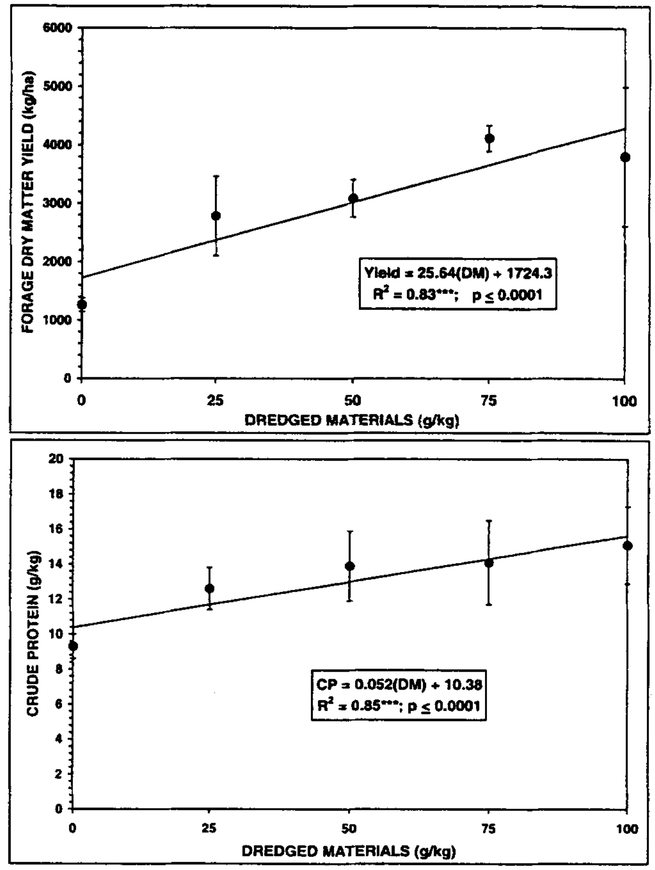

Fig. 3: Relationships of forage dry matter yield and crude protein contents of BG with increasing rates of LDM application

rates of LDM application at Julian days 546 is shown in Fig. 3 and can be described by the equation below. Forage yield variability (83%) of BG during its establishment can be explained by the addition of LDM as shown by the equation below.

$$\text{Forage Yield} = 25.64(\text{LDM}) + 1724.3 \qquad (2)$$
$$R^2 = 0.83^{***} \quad p \leq 0.0001$$

The greatest cumulative forage yield of BG of 7,623 ± 462.3 kg ha^{-1} was from plots with LDM100 and the least cumulative forage yield of 2,865 ± 115 kg ha^{-1} was from the control plots (LDM0). Cumulative forage yield of BG from plots with LDM100, LDM75, and LDM50 did not vary among each other, but was significantly greater than the cumulative yield of BG grown in plots with LDM25. Interestingly, cumulative yield of BG in plots with 25% LDM was increased by 94% over the control plots while the average yield increase of BG (averaged across LDM50, LDM75, and LDM100) was about 145% over the untreated BG (see Fig. 2).

3.2 Crude protein content

The CP content of BG with and without LDM during early establishment (Julian days 546) are shown in **Fig. 4**. Results have shown the favorable influence that LDM had on BG crude protein content during its early establishment. The CP content of BG varied significantly ($p \leq 0.001$) with varying

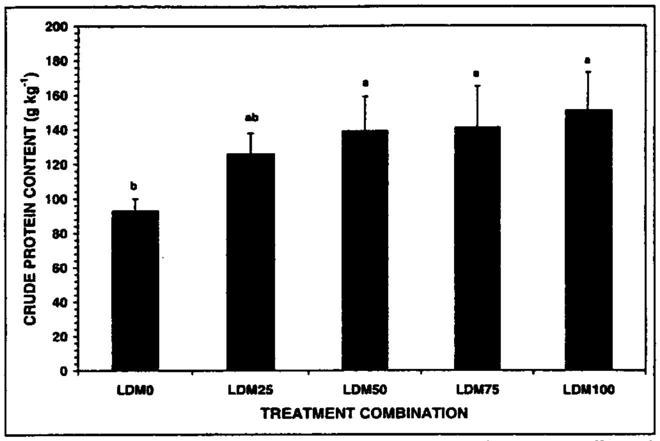

Fig. 4: Crude protein content of bahiagrass at Julian day 546 as affected by varying levels of dredged materials. Crude protein content of BG from plots with or without LDM is significantly different ($p \le 0.05$) when superscripts located at top of bars are different

levels of LDM applications. The tissues of BG with 100% LDM had the highest CP (151 ± 22 g kg^{-1}) and the lowest CP of 93 ± 7 g kg^{-1} was from the control plots (LDM0). The CP in plots with 50% (139 ± 20 g kg^{-1}), 75% (141 ± 24 g kg^{-1}), and 100% (151 ± 22 g kg^{-1}) LDM were statistically comparable, but were significantly different from the CP in the control plot (see Fig. 4). However, the CP in the control plot was not different from the level of CP in plot with 25% LDM. The crude protein of BG increased linearly with increasing rates of LDM application (see Fig. 4). The crude protein response to BG application can be described by the equation below:

$$\text{Crude Protein} = 0.052(\text{LDM}) + 10.38 \quad R^2 = 0.85^{***} \quad p \le 0.0001 \tag{3}$$

3.3 Nutrient uptake

The nutritional uptake of BG grown in unfertile sandy soils of Sumter County was enhanced significantly ($p \le 0.001$) by LDM addition. Uptake of TKN, TP, K, Ca, and Mg were remarkably increased as a result of LDM (Table 2). Uptake of Mn, Cu, Fe, and Al (Table 3) were likewise favored by varying levels of LDM, but not as much as those nutrients in Table 2.

Bahiagrass applied with of 75% LDM had the overall highest uptake of TKN, TP, K, Ca, and Mg. This rate of LDM addition had improved the uptake of BG for TKN, TP, K, Ca, and Mg by 420%, 300%, 166%, 446%, and 567%, respectively when compared with BG uptake in plots with 0% LDM (see Table 2). The uptake of BG for Al and Mo with LDM were not different from the uptake in the untreated plots while uptake for Mn, Cu, and Fe were increased by 200%, 171%, and 320%, respectively when compared with the uptake in the untreated plots (Table 3).

The overall nutrient uptake of BG especially for TKN, TP, K, Ca, and Mg were not improved by 25% LDM addition, but enhanced significantly by the addition of 50% and 75% LDM. However, application of 100% LDM did not further improve uptake of BG for TKN, TP, K, Ca, Mg, M n, Cu, Fe, Al, and Mo (see Tables 2 and 3).

4 Discussion

Results of this study have demonstrated the favorable and beneficial effects of added LDM on the early establishment of BG in pasture fields. Our results were consistent with the findings of Patel et al. (2001) who reported that grasses grown in muck-amended topsoil had adequate and comparable nutrient levels with grasses grown in golf course soils. Horticultural studies also showed encouraging results of several plant species, such as the Holly (*Ilex cornuta*), Liriope (*Liriope muscari*), oyster plant (*Rhoeo spathacea*), and bermudagrass (*Cynodon dactylon*). Forage production often requires significant inputs of lime, nitrogen fertilizer, and less frequently of phosphorus and potassium fertilizers. Dredged materials, composted urban plant debris, waste lime, and phosphogypsum are examples of materials that can be used for fertilizing and liming pastures (Chambliss 1999).

Addition of LDM had increased the levels of Ca and Mg by about 1811% and 211%, respectively when compared with the level of soil Ca and Mg among plots with no LDM application. Liming the field could have some direct and indirect ef-

Table 2: Nutrient (TKN, TP, K, Ca, and Mg) uptake of bahiagrass from plots with and without dredged materials

Treatment Combination (NS + LDM) (%)	TKN	TP	K	Ca	Mg
			kg ha^{-1}		
LDM0 – (100 + 0)	18.3 ± 1.2c (a)	2.7 ± 0.4d	14.9 ± 1.2b	7.9 ± 0.7c	2.1 ± 0.5c
LDM25 – (75 + 25)	49.3 ± 7.3bc	5.9 ± 0.9cd	14.8 ± 2.5b	22.7 ± 2.5bc	7.4 ± 1.8bc
LDM50 – (50 + 50)	69.7 ± 18.9ab	7.9 ± 1.6bc	51.6 ± 14.6a	23.3 ± 3.3bc	5.6 ± 0.8bc
LDM75 – (25 + 75)	95.2 ± 16.2a	10.8 ± 1.1ab	39.6 ± 12.0ab	43.1 ± 4.4a	14.0 ± 3.7a
LDM100 – (0 + 100)	101.6 ± 33.8a	12.0 ± 3.6a	63.0 ± 22.9a	39.6 ± 20.1ab	11.1 ± 5.2ab

(a) Means on each column followed by same letter(s) are not significantly different at $p \le 0.05$.

Table 3: Nutrient (Mn, Cu, Fe, Al and Mo) uptake of bahiagrass from plots with and without dredged materials

Treatment COMBINATION (NS + LDM) (%)	Mn	Cu	Fe	Al	Mo
			kg ha^{-1}		
LDM0 – (100 + 0)	0.04 ± 0.001b (a)	0.007 ± 0.003c	0.10 ± 0.02b	0.08 ± 0.02ab	0.0001 ± 0.001a
LDM25 – (75 + 25)	0.08 ± 0.012b	0.011 ± 0.007bc	0.34 ± 0.03a	0.12 ± 0.04a	0.003 ± 0.001a
LDM50 – (50 + 50)	0.17 ± 0.055a	0.017 ± 0.003b	0.27 ± 0.07a	0.06 ± 0.002b	0.001 ± 0.001a
LDM75 – (25 + 75)	0.12 ± 0.152ab	0.019 ± 0.006ab	0.42 ± 0.11a	0.09 ± 0.01ab	0.002 ± 0.001a
LDM100 – (0 + 100)	0.17 ± 0.078a	0.026 ± 0.006a	0.40 ± 0.12a	0.13 ± 0.03a	0.003 ± 0.001a

(a) Means on each column followed by same letter(s) are not significantly different at $p \le 0.05$.

fects on the chemical status of the soils. Perhaps the single direct benefit of liming is the reduction in acidity and solubility of aluminum and manganese (Peevy et al. 1972). Some of the indirect benefits of liming pasture fields among others would include: enhancing P and microelement availability, nitrification, nitrogen fixation, and improving soil physical conditions (Tisdale and Nelson 1975, Russel 1973, Nelson 1980). Addition of LDM resulted in higher soil pH than those plots with 0% LDM. The higher pH values for soils with LDM would favor hydrolysis reactions for Ca and Mg which increase the plant availability of these two nutrients. Higher pH values may well inactivate Al, Mn, Cu, and Fe. Our results have shown that the availability of soil Mn, Cu, Fe, and Al were significantly lowered by the addition of LDM (Tisdale and Nelson 1975).

Another equally important beneficial use of LDM is on CP and nutrient uptake enhancement of BG. Results have shown the favorable influence that LDM had on CP and nutrient uptake of BG during its early establishment. The CP of BG varied significantly with varying levels of LDM applications. The tissues of BG with 100% LDM had the greatest CP content and the lowest CP content was from the control plots (LDM0). Similar results on the effect of lime application on BG were reported by Janak (1999). The lime (4,480 kg ha^{-1}) treated BG in Texas showed an increase in CP of 11 g kg^{-1} and an increase forage yield of 823 kg ha^{-1} over the untreated BG. He reported further that liming forages proved to be economical, showing an $8.00 ha^{-1} ($18.85 $acre^{-1}$) return over the control.

Uptake of TKN, TP, K, Ca, and Mg were remarkably increased as a result of LDM application. Uptake of Mn, Cu, Fe, and Al were likewise favored by varying levels of LDM. The physiological functions performed by Ca in plants are not clearly defined, but it has been suggested that Ca favors the formation of and increases the protein content of mitochondria. Calcium is especially important in maintaining the organization of the protoplasm and providing the cement of cell walls as calcium pectate (Miller and Heichl 1995). The role played by mitochondria in aerobic respiration, indicates that there may be a direct relationship between Ca and ion uptake in general. Calcium can be considered to be related with protein synthesis by its enhancement of the uptake of nitrogen (Tisdale and Nelson 1975). The amount of soil Ca and Mg among plots with LDM were significantly higher than that in the control plots. Addition of LDM had increased the levels of Ca and Mg by about 1811% and 211%, respectively when compared with the level of soil Ca and Mg among plots with no LDM application.

5 Conclusions

Beneficial uses of dredged materials from LP, Florida are both economical and environmental. Results of our study have demonstrated the favorable and beneficial effects of added LDM on the early establishment of BG in pasture fields. Often these materials can be obtained at little or no cost to the farmers or landowners in south Florida. Results showed that dredged materials can be used as soil amendments (lime and fertilizer) for early establishment of BG in beef cattle pastures. Environmentally, dredging of sediments that are rich in $CaCO_3$ should restore the 19.4-sq km LP by removing natural sediments from the lake bottom to improve the fishery, water quality, and navigation of the lake. Our results have shown the favorable influence that LDM had on the yield of BG during its early establishment in subtropical beef cattle pastures. Bahiagrass in plots that were treated with LDM had significantly higher forage yield and CP when compared with those BG in the control plots.

6 Recommendation and Outlook

Land application of LDM may provide substantial benefits that will enhance the environment, community, and society. The heavy and trace metal contents of these materials were below the PEL and TEL (See part 1). As such, the agricultural or livestock industry could utilize these LDM to produce forages. LDM should be regarded as a beneficial resource, as a part of the ecological system. Although our results have demonstrated the promising effects of added LDM on the early establishment of BG in pasture fields, further studies are still needed not only in pastures of south Florida, but also in other areas of the world with similar climatic conditions to determine whether the environmental and ecological implications of LDM application are satisfied over the longer term.

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